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REPORT DOCUMENTATION PAGE

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1. REPORT NUMBER: NWC TP 5745	2. GOVT ACCESSION NO.
3. RECIPIENT'S CATALOG NUMBER	
4. TITLE (and Subtitle): Effect of Camouflage on Visual Detection	5. TYPE OF REPORT & PERIOD COVERED: December 1974–February 1975
6. PERFORMING ORG. REPORT NUMBER	
7. AUTHOR(s): Jeffrey D. Grossman	8. CONTRACT OR GRANT NUMBER(s)
9. PERFORMING ORGANIZATION NAME AND ADDRESS: Naval Weapons Center, China Lake, California 93555	10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS: MIPR RA 22-74, AMCMS Code 675702.12.86300
11. CONTROLLING OFFICE NAME AND ADDRESS: Naval Weapons Center, China Lake, California 93555	12. REPORT DATE: April 1975
	13. NUMBER OF PAGES: 20
14. MONITORING AGENCY NAME & ADDRESS(if different from Controlling Office)	15. SECURITY CLASS. (of this report): UNCLASSIFIED
	15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Distribution limited to U.S. Government agencies only; test and evaluation; 4 April 1975. Other requests for this document must be referred to the Naval Weapons Center.

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Target Acquisition
Vehicle Detection
Pattern Recognition
"Dazzle"
Disruptive Coloration

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

See back of form.

(U) *Effect of Camouflage on Visual Detection,* by Jeffrey D. Grossman. China Lake, Calif., Naval Weapons Center, April 1975. 20 pp. (NWC TP 5745, publication UNCLASSIFIED.)

(U) Two laboratory experiments were conducted on a terrain model to assess the effects of pattern, range, lighting, and location on the ability of subjects to visually detect tank targets. In Experiment I, each subject saw one of four patterns (MERDC, Swedish, German, or olive drab) at two ranges. The MERDC pattern took longest to detect. There was no difference due to range. In Experiment II, each subject saw all five patterns (MERDC, Swedish, British, German, and olive drab) at each of eight locations under either diffuse or bright/shadow lighting conditions. There was no difference due to pattern. It was more difficult to find a target in some locations, although location interacted with lighting condition. It took longer to detect targets when shadows were present.

AN (1) AD-B004 971
FG (2) 060400
FG (2) 150600
FG (2) 170500
CI (3) (U)
CA (5) NAVAL WEAPONS CENTER CHINA LAKE CA
TI (6) Effect of Camouflage on Visual Detection.
TC (8) (U)
DN (9) Technical publication Dec 74-Feb 75,
AU (10) Grossman, Jeffrey D.
RD (11) Apr 1975
PG (12) 22
RS (14) NWC-TP-5745
RN (18) GIDEP-E047-0916,
RN (18) GIDEP-347.90.00.00-X7-09
RC (20) Unclassified report
DE (23) *CAMOUFLAGE), (*VISUAL SURVEILLANCE, (*TARGET DETECTION, VISUAL ACUITY), PATTERN RECOGNITION, TERRAIN MODELS, COLORS, TANKS(COMBAT VEHICLES), GREAT BRITAIN, SWEDEN, GERMANY(EAST AND WEST), RANGE(DISTANCE), TIME, PATTERNS, ANALYSIS OF VARIANCE, TARGETS, SHAPE.
DC (24) (U)
ID (25) Lighting conditions, Merdc pattern.
IC (26) (U)
AB (27) Two laboratory experiments were conducted on a terrain model to assess the effects of pattern, range, lighting, and location on the ability of subjects to visually detect tank targets. In Experiment I, each subject saw one of four patterns (MERDC, Swedish, German, or olive drab) at two ranges. The MERDC pattern took longest to detect. There was no difference due to range. In Experiment II, each subject saw all five patterns (MERDC, Swedish, British, German, and olive drab) at each of eight locations under either diffuse or bright/shadow lighting conditions. There was no difference due to pattern. It was more difficult to find a target in some locations, although location interacted with lighting condition. It took longer to detect targets when shadows were present. (Author)
AC (28) (U)
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CC (35) 403019

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Effect of Camouflage on Visual Detection

by
Jeffrey D. Grossman
Aircraft Systems Department

APRIL 1975

Naval Weapons Center
CHINA LAKE, CALIFORNIA 93555

Naval Weapons Center

AN ACTIVITY OF THE NAVAL MATERIAL COMMAND

R. G. Freeman, III, RAdm., USN . . . . . Commander

G. L. Hollingsworth . . . . . Technical Director

FOREWORD

This technical report documents work conducted from December 1974 to February 1975 at the Naval Weapons Center (NWC), China Lake, Calif., as part of a joint services program on air-to-ground target acquisition supported by MIPR RA 22-74, AMCMS Code 675702.12.86300.

The Joint Technical Coordinating Group for Munitions Effectiveness has established a Target Acquisition Working Group (TAWG) under the Joint Munitions Effectiveness Manual/Air-to-Surface Division. TAWG tasks have included the definition of problem areas in airborne forward air controller operations, the description of target markers, summary of existing field test data, the evaluation of mathematical models of target acquisition, terrain and foliage masking, research on target acquisition by flare light, and the camouflage of targets.

This report presents the description and results of camouflage experiments that were conducted on a terrain model at NWC. The report has been reviewed for technical accuracy by Ronald A. Erickson. It is released at the working level for information only.

Released by
PAUL B. HOMER, *Head*
Weapons Systems Analysis Division
4 April 1975

Under authority of
M. M. ROGERS, *Head*
Aircraft Systems Department

NWC Technical Publication 5745

Published by . . . . . Technical Information Department
Manuscript 5362/MS 75-47
Collation . . . . . Cover, 11 leaves
First printing . . . . . 245 unnumbered copies

CONTENTS

INTRODUCTION

Until recently, pattern painting of military vehicles to achieve camouflage has received little systematic scientific scrutiny. During both World War I and II, the U. S. Navy experimented with patterns painted on warships, attempting to reduce the conspicuity of the ships either by reducing their visibility or by changing their physical appearance.[1] "Dazzle" patterns used disruptive coloration to change the appearance of forms and were found to be very effective in confusing a ship's heading, speed, and distance to observers. However, confusion was found to be much easier to attain than invisibility. The patterns that were eventually used were generally artistic productions based on the dazzle principle.

The U. S. Army has also been engaged in research on pattern painting. In one study[2] a qualitative evaluation of several patterns painted on armored vehicles was made. The criteria for selection of an optimum pattern, however, included logistics concerns as well as concealment. The patterns that were tested were, again, artistic productions designed to blend the colors of a vehicle into the background and to distort the geometric lines and overall configuration of the vehicle. Four-color patterns were evaluated. The pattern type finally selected is now referred to as the MASSTER*/MERDC or MERDC pattern.

Jarvis[3] then compared the detection and identification ranges of vehicles painted with the MERDC pattern with those painted with the Swedish, U. S. Army (Europe), British, German, and standard olive drab patterns. She reported that there was no statistical difference between the olive drab and the British pattern, nor any differences among the German, Swedish, USA (Europe), or MERDC patterns. A statistically significant difference ($p < .10$) between these groups was reported, although it was above the generally accepted chance level. Jarvis suggested that the British and olive drab vehicles might have been more easily detected than the other vehicles (Figure 1).

Jarvis listed several possible explanations for the inconclusiveness of the tests. Among these were the small sample size, differences in target locations, inexperienced subject groups, and the uniqueness of the background against which the targets were viewed. In addition, she concluded that the *patterns were not resolvable* at the time of detection and that color blend was more likely the factor that was evaluated rather than pattern type.

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* Modern Army Selected Systems Test. Evaluation, and Review. Headquarters in Fort Hood, Texas.

[1] Sumrall, Robert F. "Ship Camouflage (W WW II): Deceptive Art," US NAV INST, PROC, Vol. 99, No. 2 (February 1973), pp. 67-81.

[2] U. S. Army Mobility Equipment Research and Development Center. *Camouflage Pattern Painting Report of USAMERDC s Camouflage Support Team to MASSTER*, by A. H. Humphreys and S. V. Jarvis. Fort Belvoir, Va., MERDC, February 1974. (Report No. 2090, publication UNCLASSIFIED.)

[3] U. S. Army Mobility Equipment Research and Development Center. "Technical Memorandum: Fort Knox Test of Camouflage Pattern Effectiveness," by S. V. Jarvis. Fort Belvoir, Va., MERDC, August 1974. (Memorandum UNCLASSIFIED.)

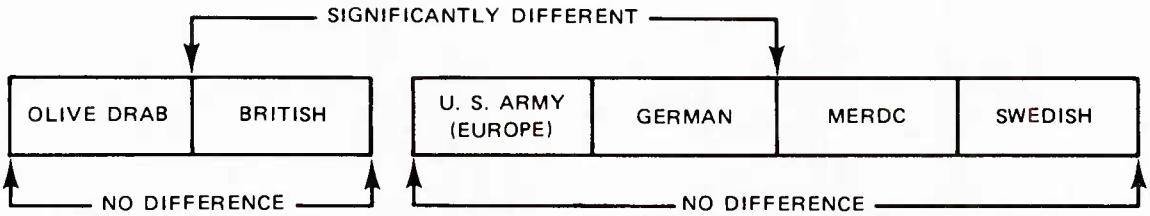

FIGURE 1. Summary of Jarvis' Results.

Grossman and Whitehurst[4] conducted two preliminary experiments to determine whether differences in the patterns of painted surfaces had a measurable effect on an observer's ability to detect a target. The experiment was conducted under varying light conditions, using a desert background. The results indicated that there were differences in detection times and the probabilities of detection due to camouflage technique. It was reported that three factors (color, pattern, and surface texture) were varied, and it was difficult to ascertain which of the three was most responsible for making the targets difficult to see.

OBJECTIVE

The objective of the two studies reported here was an evaluation of several camouflage paint patterns now in use or under consideration internationally and an investigation of the effects of range, target location, and lighting conditions on the times and probabilities of detection of patterns. (Painted patterns are defined here as the total configuration of a paint scheme, including the contours of the lines, the colors, color proportions and blends and the number of colors.)

OVERVIEW

Scale model tanks were painted with camouflage patterns and placed on a terrain model one at a time. The terrain model was predominantly forested, and contained sandy and rocky areas. Subjects were required to search the terrain as quickly as possible to find the target vehicle. They were scored on their search time per trial, a measure that was used to indicate the relative effectiveness of the camouflage patterns.

[4] Naval Weapons Center. *Preliminary Experiments on the Visual Detection of Camouflaged Targets,* by Jeffrey D. Grossman and Hubert O. Whitehurst. China Lake, Calif., NWC, December 1974. (Technical Note 4011-20, publication UNCLASSIFIED.)

EXPERIMENT I

METHOD

Design

A 2 x 4 completely randomized factorial design with repeated measures on one factor was used in this experiment (Figure 2). The independent variables were pattern and range, the dependent variables were time until detection and percent correct detections. Each subject was shown only one pattern 19 times: 3 practice and 16 data trials. For the data trials each pattern was shown four times in each one of four general quadrants of the search area. The order in which the quadrants were used as a location was randomized.

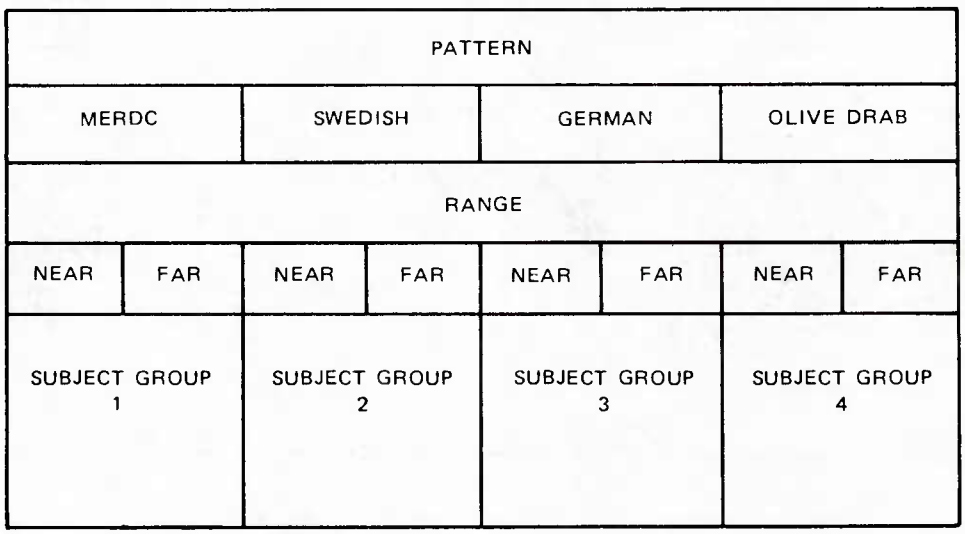

FIGURE 2. Experiment I Design.

The range from the observer to the target varied between a simulated 425 and 550 meters. For half of the trials the target was placed in the closer 100 meters and the other half it was placed in the further 100 meters.

Subjects

Twenty-eight employees of the Naval Weapons Center, China Lake, Calif. (10 females and 18 males), served as subjects for this experiment All of the subjects demonstrated either corrected or uncorrected near and far binocular visual acuity of 20/20 or better as measured by a Bausch and Lomb Vision Tester. Each subject also demonstrated normal color vision as measured by Dvorine Pseudo-Isochromatic Plates.

Apparatus

The search area was a square, 8- by 8-foot terrain model with a center 19 feet from the subject position. The simulated slant range from the subject to the model was 378 meters to the front and 580 meters to the back. The subject to-target depression angles varied from 14 to 19 deg below the horizon. The experimental setup is depicted in Figure 3.

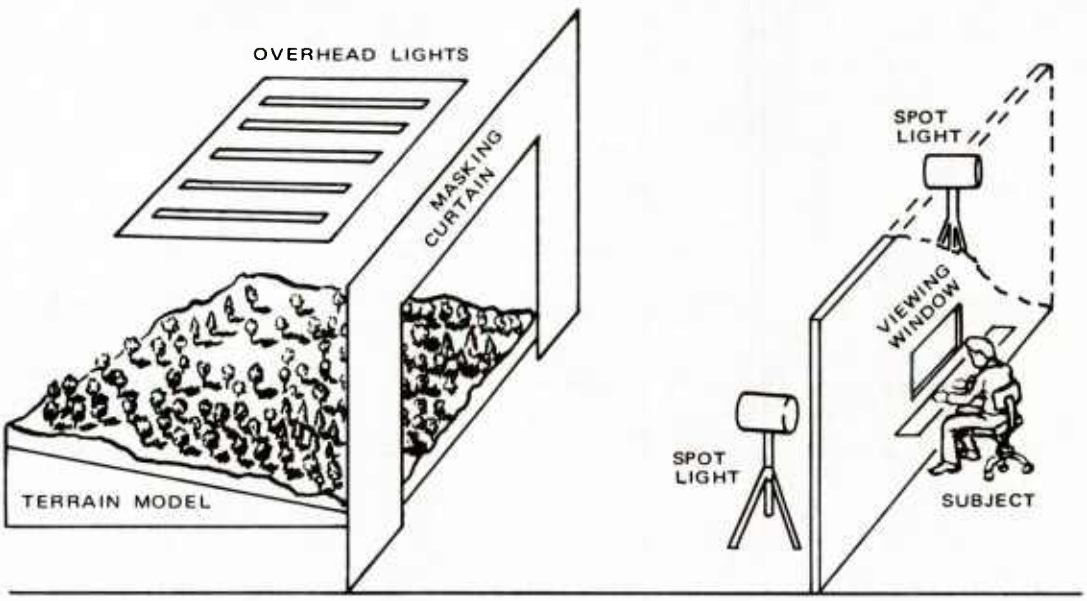

FIGURE 3. Experimental Setup for Experiment I.

The terrain was a three-dimensional, 84:1 scale model simulating a square area approximately 200 meters on a side (Figure 4). It contained numerous trees and shrubs of different types and heights and varied in color from light greens, browns and yellows to dark greens and browns. Areas of sand and rocks were also included.

SWEDISH MERDC GERMAN OLIVE DRAB

FIGURE 4. Photographs of Tank Targets and Terrain Model.

Lighting was provided by two Berkey-Colortran Model 100-412 lights which contained 1000-watt, 3200°K bulbs (Figure 3). Light diffusers and dichroic filters were placed in front of each light. Sixteen fluorescent lights located directly above the terrain model also were used. The total lighting effect was similar to that of a bright, overcast day where shadows were slightly visible. The luminance of the background varied between 9 and 12 ftL.

Targets

Four 84:1 scale model M-60A medium tanks served as targets. The average subtense of the target at the subject's eyes was 58 minutes of arc. Each tank was painted with a different camouflage pattern. The patterns were based on the MERDC, Swedish, and Federal Republic of Germany (German) designs; a single-color, olive drab paint (no star) was also used. These are shown in Figure 4. Two tanks were painted with four colors of Pactra brand flat enamel: olive drab, flat green, earth yellow, and black. The two-color German design used only the flat green with olive drab.

The luminance of the targets varied between 7 and 11 ftL, depending on their location in the search area. All the targets were of nearly equal luminance when positioned in the same way at the same place.

The tanks were always oriented at 45 deg to the subject's line of sight and were one-third masked from the subject's view by trees on the terrain model.

Subject Room

The subjects were seated in a sound-proofed room during the experiment. Their view of the terrain model through an opening in the wall was masked by a shutter. The upper half of the shutter could be lowered by the experimenter to reveal a wall 25 feet away (just above the search area), on which was printed a large half-circle. By lowering the remainder of the shutter, the subject could start a digital timer. The timer was stopped by a subject-controlled switch.

Procedure

Each potential subject was first given a visual acuity test and a color vision test. If the subject met the test requirements he was then seated, given the instructions (see Appendix), and allowed to familiarize himself with the shutter apparatus.

An individual trial began after one experimenter placed the target within the search area and gave a verbal OK to the other experimenter. The second experimenter then lowered the upper part of the shutter, revealing the half-circle on the wall. The subject focused on the half-circle and accommodated to the light in the terrain model room for approximately 3 sec. He then pulled a cord, lowering the rest of the shutter and starting the timer. He immediately began searching for the target. When the target was detected the subject flipped a switch to stop the timer He then called out the location of the target. The shutter was raised, the time was noted, and the next trial was started.

The subject was given 10 sec to locate the target. If no detection was made within that period, the experimenter called time, raised the shutter, and recorded a 10-sec search time. Each subject saw the same target a total of 19 times in succession.

RESULTS

The cumulative frequency of detection times combined over subject group and range is presented for each target in Figure 5. The olive drab, Swedish, and German pattern results are grouped very closely, while the MERDC pattern was more difficult to detect.

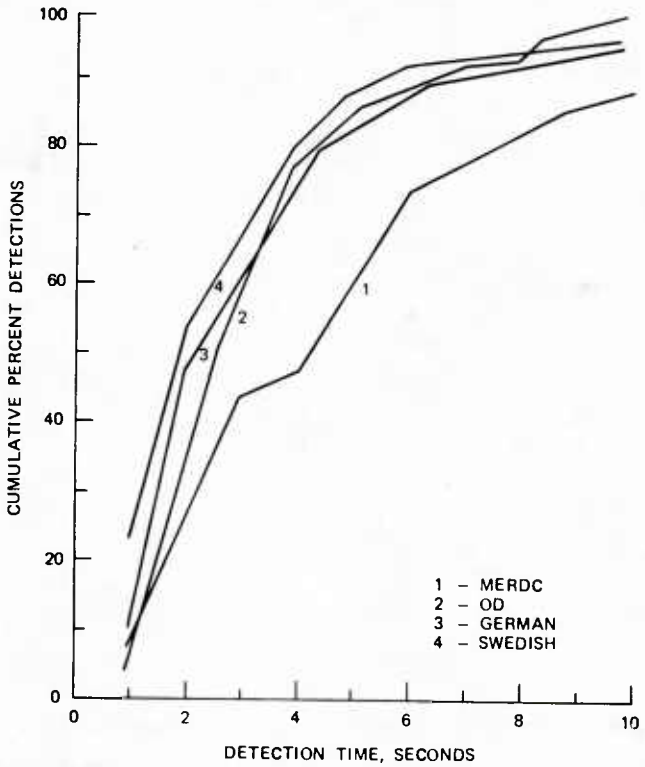

FIGURE 5. Cumulative Frequency of Detection Times Combined Over All Subjects and Two Ranges.

A two-factor analysis of variance was performed on the detection time data using pattern type and range as the main factors (Table 1). The results indicate that range did not significantly affect detection time, nor did range interact with pattern type. However, pattern did significantly affect detection time more than would be expected by chance. A Newman-Keuls test indicated that the MERDC-patterned vehicle was more difficult to detect than any of the other vehicles. There was no difference in detection time between the other three vehicle patterns. These results are shown in Figure 6.

TABLE 1. Analysis of Variance of Detection Time Scores.

Source of variance	df	MS	F
Patterns (P)	3	10.4	7.4[a]
Ranges (R)	1	0.3	0.2
P x R	3	2.1	1.5
Subjects/P x R	48	1.4	. . .
Total	55	1.9	. . .

NOTE: df = degrees of freedom; MS = mean square; F = ratio.
[a] $p < .001$.

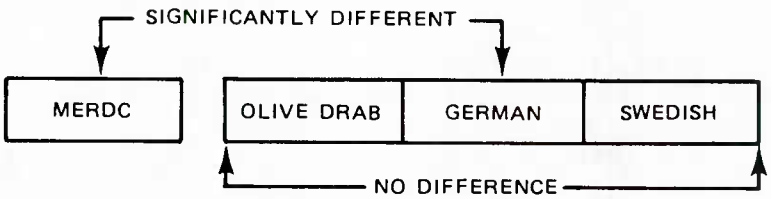

FIGURE 6. Summary of Results of Newman-Keuls Test on Detection Time Data.

Another two-factor analysis of variance was performed on the frequency of detection in less than 5 sec (the approximate median detection time). The results (Table 2) are identical to the detection time data shown in Figure 6.

TABLE 2. Analysis of Variance of Frequency of Correct Detections in Less Than 5 Seconds.

Source of variance	df	MS	F
Patterns (P)	3	16.0	9.4[a]
Ranges (R)	1	0.1	0.1
P x R	3	1.5	0.9
Subjects/P x R	48	1.7	...
Total	55	2.5	...

[a] $p < .001$.

DISCUSSION OF RESULTS

There were several ways in which the patterns used in this experiment varied. The contours of the lines in the patterns were different, varying from the single color to splotches to sharp angles and straight lines to curved, flowing lines. The color mix or proportions were also different, varying from one dominant color to four colors of nearly equal proportion. The number of colors used in the patterns was different; one, two, and four colors were used. Finally, the colors and color blends varied by target.

Search performance cannot be related to specific differences between the patterns. Three of the patterns were different on all of the above factors yet were equally detectable. The MERDC and Swedish patterns were similar in several respects but had statistically different detection times. One possible explanation is that the subject groups were not matched on their ability to detect camouflaged targets. If so, a replication of this experiment should obtain different results.

It would also be useful to investigate the effect of lighting conditions on the detectability of patterns.* Distinct shadows in the background may improve the effect of some patterns and lessen the effect of others.

Finally, although range to the target had no significant effect in this study, other ranges should be investigated. There may well be different ranges at which each pattern becomes effective.

* Varied lighting conditions were investigated in Experiment II of this report.

EXPERIMENT II

METHOD

Design

A 2 x 5 x 8 split plot factorial design (SPF 2.58)[5] was used in this experiment (Figure 7). The independent variables were lighting conditions, painted pattern, and target location. The dependent variable was search time. Each subject was shown a pattern several times in succession with no practice trials, then shown another pattern several times and so on, until he had seen all five patterns.

LIGHTING CONDITION	PATTERN				
	MERDC	SWEDISH	BRITISH	GERMAN	OLIVE DRAB
	LOCATION				
	1–8	1–8	1–8	1–8	1–8
DIFFUSE	SUBJECT GROUP 1				
BRIGHT/ SHADOW	SUBJECT GROUP 2				

FIGURE 7. SPF 2.58 Experimental Design for Experiment II.

The order in which the five blocks of patterns was presented was counterbalanced across subjects. The order in which the target locations on the terrain model were used was randomized within each block. Half of the subjects saw a diffuse lighting condition (similar to an overcast sky); half saw a bright/shadow condition (direct sunlight).

The range from the observer to the target varied between a simulated 425 and 550 meters. For half of the trials each target was placed in the further half of the search area (locations 1–4), and for half it was placed in the closer half (locations 5–8).

[5] Kirk, Roger E. *Experimental Design: Procedures for the Behavioral Sciences.* Belmont, Calif., Brooks/Cole Publishing Co., 1969. p. 302.

Subjects

Thirty employees of the Naval Weapons Center (4 females and 26 males) served as subjects for this experiment. All of the subjects demonstrated either corrected or uncorrected near and far binocular visual acuity of 20/20 or better as measured by a Bausch and Lomb Vision Tester. Each subject also demonstrated normal color vision as measured by Dvorine Pseudo-Isochromatic Plates.

Apparatus

The search area was nearly identical to that described in Experiment I. Some of the trees were rearranged to provide new target locations and several areas of dirt and rocks were added. The range to the terrain model and the viewing depression angle also remained the same.

For the diffuse lighting condition–where no shadows were present–four 48-inch fluorescent lighting fixtures with two 40-watt bulbs each, were located directly over the terrain model. For the bright lighting condition–where dark shadows were present–two Berkey-Colortran Model 100-412 lights that contained 1000-watt, 3200°K bulbs were located over the near left corner of the terrain model (Figure 8).

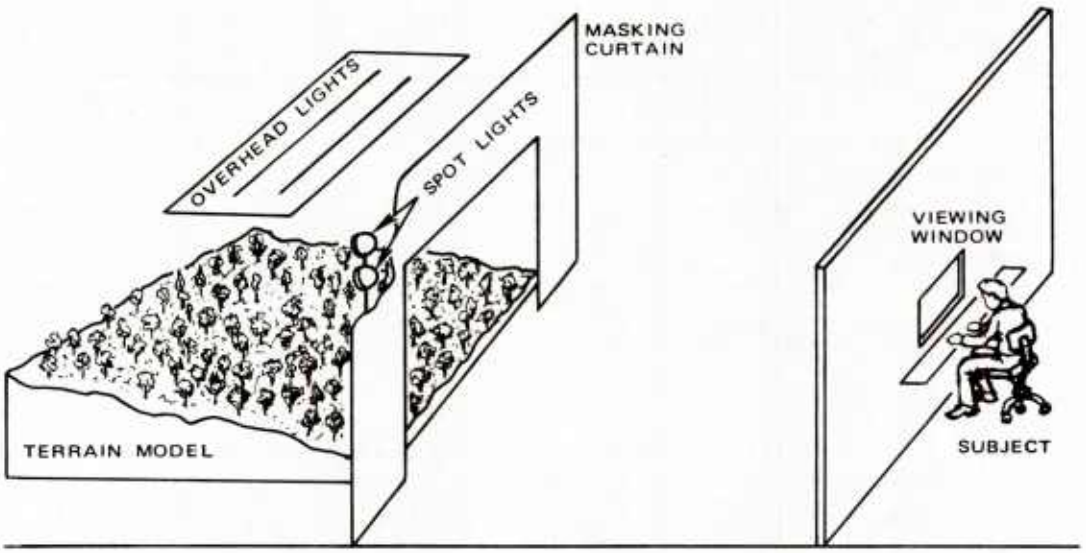

FIGURE 8. Experimental Setup for Experiment II.

It was not meant to simulate cloudy or sunny days exactly since color temperatures and luminances of such days are difficult to attain indoors. However, the lighting conditions used did provide two markedly different lighting conditions sufficient to test the effects of lighting on paint patterns.

In the diffuse lighting condition the luminance of the targets varied between 2.0 and 5.0 ftL, depending on location. The background luminance was 5.5 ftL ±1. At a given location the luminance of the targets varied by about 10%. In the bright/shadow condition the luminance of the targets varied between 5 and 14 ftL. However, part of the target was in shadow in all locations. The part of the background not in shadow varied between 9.0 and 15.2 ftL.

Targets

Five 84:1 scale model M-60A medium tanks served as targets. The average subtense of the target at the subject's eyes was 58 minutes of arc. Each tank was painted with a different camouflage pattern. The patterns were based on the MERDC, Swedish, Federal Republic of Germany (German), and British designs; a single-color olive drab paint (no star) was also used. These are shown in Figure 9. Two tanks were painted with four colors of Pactra brand flat enamel: olive drab, flat green, earth yellow, and black. The two-color British and German designs used only the flat green with black. The designs were based on information and drawings provided by the U. S. Army Mobility Equipment Research and Development Center, Fort Belvoir, Va.

MERDC GERMAN SWEDISH BRITISH OLIVE DRAB

FIGURE 9. Photograph of Tank Targets for Experiment II.

The tanks were always oriented at 45 deg to the subject's line of sight and were completely visible (unmasked) to the subject. There were each shown one time in each of the eight locations on the search area.

Subject Room

The subject room was the same as that described in Experiment I.

Procedure

Each potential subject was first given a visual acuity test and a color vision test. The subject then participated in another camouflage experiment, viewing different targets on the same terrain model. He was then given the instructions for this study (see Appendix).

An individual trial began after one experimenter placed the target randomly within the search area and gave a verbal OK to the other experimenter. The second experimenter then lowered the upper part of the shutter, revealing the half circle on the wall The subject focused on the half-circle and accommodated to the light in the terrain model room for approximately 3 sec. He then pulled a cord, lowering the rest of the shutter and starting the timer. He immediately began searching for the target. When the target was detected the subject flipped a switch to stop the timer. He then called out the location of the target. The shutter was raised, the time was noted, and the next trial was started.

The subject was given 8 sec to locate the target. If no detection was made within that period, the experimenter called time, raised the shutter, and recorded an 8-sec search time. Each subject saw the same target eight times in succession, continuing through the five targets for a total of 40 trials. Before each target was presented for the first time, it was placed on the terrain model for familiarization of the subject to the new target.

RESULTS

The cumulative percentages of detection times combined over subjects are shown in Figures 10 and 11. In Figure 10 (data combined over location and subjects), the targets are not shown individually for the diffuse lighting condition because they fell virtually along the same line. Some variation between targets existed in the bright/shadow condition. The primary observations to be made are that the targets are more easily detectable when shadows are not present, and that there is little difference between the camouflage patterns.

In Figure 11 (data combined over targets and subjects), it appears that when the lighting is diffuse the targets are equally difficult to detect in the near and far portion of the search area. In the bright condition, however, the more distant targets are more difficult to detect. Part of this difference may be due to slightly lower luminances at the corner of the search area opposite the lights. However, this result still obtained for near and far locations of equal luminance.

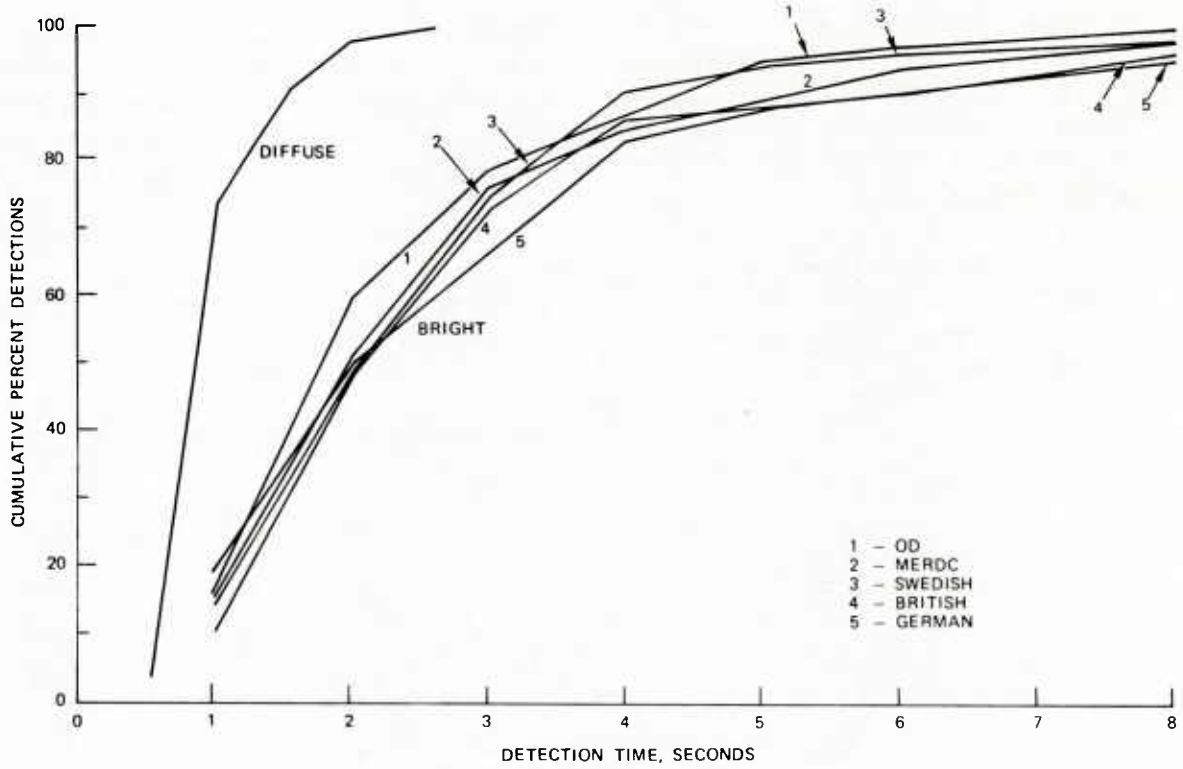

FIGURE 10. Cumulative Percent of Detection Times for Each Target and Two Lighting Conditions.

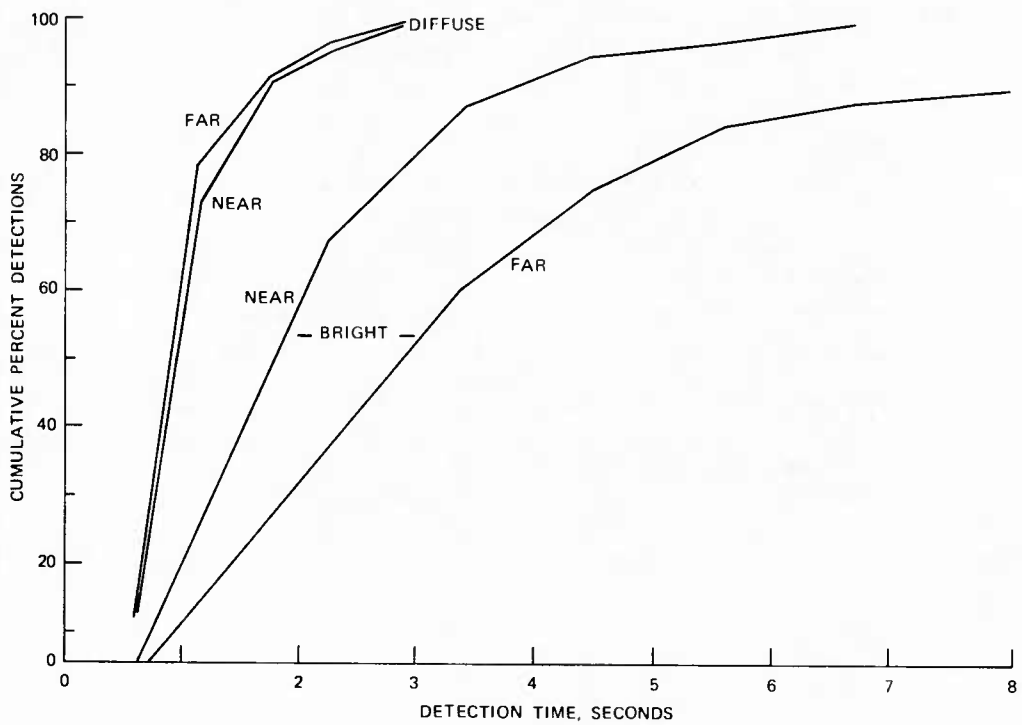

FIGURE 11. Cumulative Percent of Detection Times for Two Ranges and Two Lighting Conditions. Locations 1–4 were far range; locations 5–8 were near range.

A three-way analysis of variance (pattern x location x lighting) was performed on the detection time data (Table 3). The results indicated that pattern did not significantly affect detection time. Detection time was, however, significantly affected by location ($p < .01$) and lighting condition ($p < .01$). In addition, the only significant interaction was between these two factors ($p < .01$), which was due to the range effect under bright lighting. The relative difficulty among the locations did not change significantly as a function of lighting condition.

TABLE 3. Summary of Analysis of Variance of Detection Time Scores.

Source of variance	df	MS	F
Location	7	47.34	26.82[a]
Pattern	4	2.15	2.02
Subject within groups	28	9.90	...
Lighting	1	769.12	77.7[a]
Location x pattern	28	0.71	0.90
Location x subject within groups	196	1.77	...
Pattern x subject within groups	112	1.06	...
Location x lighting	7	36.80	20.80[a]
Pattern x lighting	4	2.32	2.17
Location x pattern x subject within groups	784	0.79	...
Total	1,189	...	...

[a] $p < .01$.

Ignoring absolute differences in means, a rank was assigned to the mean detection time of each target for each subject and Friedman's analysis of variance by ranks was performed. The results suggested that in the bright/shadow condition, the order of difficulty shown in Table 4 is likely to occur more often than would be expected by chance ($p < .05$). In the diffuse condition, there was no significant difference in ranks among the patterns; that is, the order shown is no more likely to occur than any other order.

TABLE 4. Mean Ranks of Patterns for Two Lighting Conditions.

Lighting condition	Rank[a]				
	1	2	3	4	5
Diffuse	Swedish	Olive drab	MERDC	German	British
Bright/shadow[b]	MERDC	German	British	Swedish	Olive drab

[a] 1 = difficult; 5 = easy.

[b] $p < .05$

DISCUSSION AND RECOMMENDATIONS

The data generated earlier by Jarvis[3] and that obtained in the two experiments reported here strongly suggest that a painted pattern is not an important factor in reducing the detectability of a vehicle. In fact, there is little evidence to suggest that a pattern is more effective than a single color when the color used is similar to the color in the background. The weight of evidence also suggests, not surprisingly, that target location and light conditions do significantly affect the detectability of a vehicle. More importantly, neither will interact with pattern to produce differences in pattern effectiveness at the ranges tested.

Furthermore, in Experiment II, where the target was completely unmasked, the median detection time in the diffuse condition was about 1 sec. In Experiment I, with similar lighting but where the target was one-third masked, the median detection time was about 2.5 sec. It is certainly not surprising that hiding part of a target increases search time, but the results indicate that obliterating a portion of the outline mechanically rather than by pattern painting is a far more effective method of camouflage. Several subjects commented that even though the patterns were visible, the vehicle outline was very conspicuous.

It is possible that pattern painting becomes an effective camouflage technique at other ranges than those tested. Further study of the effects of range on the detectability of painted patterns should be undertaken.

One other ramification of these results is that less effort might be spent on investigations of pattern (where pattern means contours, colors, proportions, and blends) and more effort spent on determining how and where to locate a vehicle under different conditions. Additionally, more effort could be spent on investigations of optimum colors for different locales and on alternative methods of mobile camouflage—such as textured surfaces, fender skirting, and shape disrupters.

Appendix
INSTRUCTIONS TO SUBJECTS

EXPERIMENT I

"This is an experiment on camouflage. The purpose of this study is to determine the effect of paint color and pattern on your ability to detect a test target.

"Here is the test target. You will see it located randomly in the search area you see through the small window. One and only one target will be seen during each trial.

"If you will be seated you can see the search area through the window. One experimenter will place the target in the area while your view is masked by this shutter and flap. When we are ready, this flap will be lowered and you may take about 3 seconds to focus on that 'C' on the rear wall. When you are ready, after about 3 seconds, pull this string with your right hand. This lowers the shutter. Immediately begin searching for the target. You will have 10 seconds to locate it. As soon as you see it flip this switch to stop the timer. Flip it only one way. On the next trial you will flip it the other way. If you fail to find the target in 10 seconds, I will call time and raise the shutter. After you find the target and have flipped the switch, please describe the location of the target, i.e., upper left, lower left, upper right, lower right. Do you have any questions?"

EXPERIMENT II*

"This next experiment is, again, to help us evaluate several different patterns of camouflage.

"Your task is nearly identical to the last experiment except that now you will be searching for a camouflaged tank. Furthermore, you will have only 8 seconds to find it.

"Here are the five targets. You will see each one a number of times in succession. Again, before each set of trials we will place it on the front of the search area. The operation of the shutter and switches and your response describing the location remain the same.

"Remember, you are looking for a tank and you have 8 seconds before we call time.

"Do you have any questions?"

* These instructions were given immediately following another experiment.

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